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THE ABBOT'S RIPTON RAILWAY ACCIDENT.

THERE can be no question but the Abbot's Ripton catastrophe has opened up to the mind of the railway traveller another source of danger. Hitherto snowstorms have been regarded mainly as sources of impediment to railway working. Trains have been "snowed up" and their passengers subjected to long and tedious delays, in many cases attended with much discomfort; but it has been left to the Ripton accident to discover the new feature of danger attending such changes of temperature. Whether the snow clogged the signal arms, or whether its accumulation upon the wires by which the signals were worked was such as to prevent the true action of the signal, matters not. To the snow, primarily, there seems little doubt the accident was due. The Railway Company's arrangements, or the manner in which these arrangements were carried out by those on the spot, we have no desire to discuss. The broad facts of the case are these. When at a temperature above freezing, a snow storm of unusual density occurred. The snow clung to the wires, it clogged the signals, and prevented the arms rising to danger at the moment when they were most needed. As is usual fog-men were sent out, but some time unavoidably elapsed ere they could be got to their posts. In the meanwhile the double accident arose.

One very noticeable fact here comes before us. The signalman in each instance was under the impression his signals were working right. He had placed them at danger so far as he was aware, and he had blocked his sections. A verdict has been pronounced condemning the block signals. We know not what this means. The evidence adduced was to our judgment perfectly satisfactory as regards the efficient working of the "block." Possibly those who arrived at this conclusion may have regarded the out-door system of signals as a part and parcel of the block system, but to those acquainted with railway working the block system means purely the electrical instruments and the mode on which these instruments are worked. The out-door signals are governed by them; they are the exponents of the electrical signals "clear" and "blocked," but they are worked by different means, under different control, and are attended to by a totally distinct staff of men. To blame the block signals is to saddle the wrong horse: the electrical signals performed their work well; the failure lay with the out-door signals. Stress has been laid upon the fact that the signalmen were oblivious to the failure of their signals, and the fact is patent that had they been aware of it means were within their reach by which the drivers might have been advised of their danger. The great point, then, is to give these men, not only those so intimately connected with this unfortunate affair, but *every man who has the handling of signals*, means by which he may assure himself whether those signals are acting correctly or not. Distant and other signal repeaters have been in use for years. The need for them was felt almost with the introduction of the locking frame, and it was first supplied mechanically, but electric repeaters very shortly followed, and their truthfulness and economy, as compared with their predecessors, may be said to have left them completely masters of the field. Mr. Cockshott, in his evidence before the coroner's jury, bore witness to the large amount of money (some £80,000) which the Great Northern Railway Company is spending annually upon its signals, and it cannot be said that, in this instance, parsimony has prevented the application of so useful and inexpensive an agent as the electrtcal repeater. Still there can be no doubt that had they been in use at this fatal spot much misery might have been saved, and great expense to the company itself avoided. Out of every evil comes some good! Let us hope the experience of this sad affair will induce railway companies to protect the lives of their passengers, no less than their own property, by the adoption of a means as simple as cheap. Snow storms will again arise. It may be years before they may come attended with a temperature so peculiarly necessary to produce such another condition of circumstances, but it may be to-morrow. Anyway, sooner or later, it is sure to recur, and all we can do is to urge railway managers to take time by the forelock and be ready.

There are at the same time other points to which the attention of railway companies might, apparently with advantage, be directed. We have seen that delay attended the dispatch of the "S. P." message annnouncing the collision. We do not concur in the censure passed upon those engaged in its transmission for adhering to the set formula which the rules of the service prescribed. If these rules direct that all such messages shall be preceded by the code-time, and number of words, those charged with their transmission should not be blamed for observing them, even in moments of such emergency as that referred to. Nor do we think that where such rules exist their non-observance at such a moment would be likely to, in any way, facilitate the communication, but that it would rather retard it, inasmuch as the receiving clerk would stop the communication for the missing formula. The fault rests with the framers of such rules. It is preposterous to suppose that the prefix which should obtain the chief precedence is that for an engineer's message. For all railway traffic there should be a *danger* prefix, D P, or other equally expressive code, which should have the pre-eminence, and be empowered to stop anything else passing, whether in the middle of the communication or not, and which

should be as simple as the occasion would admit, regulated with codes or checks of any kind. If we mistake not, "S P" was, at one time, applicable only to very special matter, but, doubtless the want of strict supervision in checking its use, where not justified by the importance of the communication, coupled with the ever-growing telegraph work of a large railway has reduced its value.

The other point to which we desire to refer is the not unfrequent overcrowding of railway circuits. In the Postal Telegraph Service the number of instruments to which a needle circuit is limited never exceeds six; with railways the number even exceeds, at times, twice that number. Now, when it is remembered that these circuits are tended by boys, or, if by men, by men who have slight knowledge of telegraph work, and who can work but slowly, the condition at which the traffic on such a circuit arrives under a pressure of messages is evident. Each one will be earnest, and many not over scrupulous as, to the means they employ to dispose of what messages they have, without any consideration whatever for others. Fighting and squabbling will arise, and delay must ensue. The remedy for this is the reduction of the number of instruments. This may mostly be arranged at little cost. Railway companies have now the maintenance of their telegraphs in their own hands. The maintenance of a few additional miles of wire cannot affect them greatly, whilst the advantage of a speedy communication will extend to every branch of the service and be hailed with delight by all.

THE RECENT BREAKAGES OF THE DIRECT UNITED STATES COMPANY'S CABLE.

We have been furnished with a copy of the report, bearing date the 21st ult., of Sir William Thomson, of Glasgow, and Mr. T. J. Bramwell, of Great George-street, Westminster, upon the fractures which have occurred of late upon the cable belonging to the Direct United States Company. The examination of the broken ends, and the sections of cable which have been recovered, was entrusted to these two gentlemen, whose names alone form a sufficient guarantee of the care and thoroughness with which such a work as this would be carried out.

Four pieces of cable were submitted to them: the first which was examined, formed the Irish or Eastern side of the fracture that took place on the 27th of September last, in latitude 45° 7′ 12″ north, and longitude 54° 21′ 24″ west, and in a depth of about 70 fathoms. The tapering down of the ends of the wires, which is characteristic of good ductile metal in the act of breaking, combined with the general appearance of the broken cable, could admit of only one conclusion being drawn, and that, to quote the words of the report, is that "the breakage was not due to any decayed or imperfect condition of the cable, and also that it was not due to chafing of the cable against a rock, nor to any influence of an abrading or of a crushing character, but that the breakage has occurred in a perfect cable, and through thoroughly sound metal, and was caused by the whole having been torn asunder under a violent tensile strain." And further "that this violent tensile strain must have been caused by an implement such as the arm of a grapnel or the fluke of an anchor, which implement having been brought into contact with the cable on the western side of the fracture, has run along it eastward driving the serving into the heap which is now accumulated on the piece to the east of the fracture, and forms there a thick mass round the cable for a length of 13 inches; this accumulation of serving then arrested the further progress of the implement, as is proved by the mark on the iron sheathing left by the implement at the point where it was stopped by the accumulation of serving, and this stoppage having been effected the final strain which broke the cable commenced."

A portion of the cable picked up at the time this first fracture was repaired, although it was down for nearly a year and a half, is stated to be "absolutely and entirely sound; in fact, it has all the appearance of a new cable, the external compound being in perfect condition."

The two sides of the second fracture, namely, that which occurred on the 10th December last, in latitude 44° 51′ 45″ N., longitude 58° 52′ 0″ W., and in about 120 fathoms of water, were next examined. An inspection of these has led to the same conclusion as to the cause of the second fracture, and the examiners have no hesitation in asserting that this fracture, like the first, occurred "in a perfect cable and through thoroughly sound metal, and that the fracture is due to that metal having been torn asunder under violent tensile." When the second fracture was repaired, about 12 knots of cable were recovered, and these were examined by Sir William Thompson and Mr. Bramwell, on the 31st of January on board the *Faraday* at Gravesend. The cable was coiled in four flakes, the upper one only being exposed to view. This flake was "minutely examined, and found to be thoroughly and completely sound, without indication of deterioration of any kind or description, either to the outer serving or to the compound on the serving. In fact, it was impossible to tell, except from the absence of the whitewash, usually applied to new cable to prevent one part from adhering to another, that it was not a newly manufactured cable coiled in the tank for the first time. With this qualification, however, that for a few of the coils near to the end, the outer serving was slightly chafed from having been dragged along the bottom in the act of being hauled in. Seeing how entirely satisfactory this top flake was, and observing that in the eye of the coil a similar satisfactory appearance was presented by the inner turns of the three lower flakes, it was not thought necessary to have the cable uncoiled out of the tank for the purpose of examining its whole length."

Experiments were then made as to the breaking strain of this recovered cable at the works of Messrs. Brown, Lenox, and Company, and from the results which were obtained with the specimens subjected to the test the power of resistance of the cable to a direct tensile strain is set down at seven tons. Sir William Thomson and Mr. Bramwell apparently find it impossible to speak

in too high terms of the condition of the cable. Their experiments and examinations, to quote their own words, have convinced them that the cable is "one of an extremely strong form, that it has suffered no deterioration whatever from its immersion for a period of about a year and a half in the sea, and that the fractures have been caused by violence applied by an implement, and not by decay, and not by any abrasion, or rubbing, or any influence of that kind. The gutta percha of the cable at every part of the recovered specimens exposed to view was in thoroughly sound and perfect condition. Sir William Thompson's assistant, Mr. Bottomly, tested in water at a temperature of 43°, in the tank on board the *Faraday*, the twelve-mile length referred to above, and found its insulation to be 4,340 megohms per knot. This reduced, according to the usual scale for gutta percha, gives 383 megohms per knot at 75°, which proves it to be free trom fault, as might have been anticipated from the already stated excellent condition presented by the cable externally."

To the question how came a strain to be applied of such a nature as to break a cable like this, the report, as one would expect, furnishes no satisfactory reply. The probability of its having been accidentally broken by some fishing vessel can no longer be entertained after reading the cogent arguments to the contrary which are here adduced. Apart from the extreme difficulty, if not absolute impossibility, of so violent a strain being exerted by any craft that might let go its anchor in these waters, the immunity of the cable from rupture or damage of any kind during the greater part of two fishing seasons, is evidence of the strong improbability of the repeated ruptures which have since occurred being produced accidentally by fishing vessels in pursuit of their ordinary calling.

The report is replete with interest, and merits the consideration of all; the cause of the breakages it cannot tell us, but it can and does tell us that what many would fain make believe was the cause must now be eliminated, and that the "accident" which in less than three months twice broke a cable of the highest class, is one which is apt to occur but which cannot, in the present state of our knowledge, be included among what have hitherto been known as accidents.

POST OFFICE TELEGRAPHS.

THE review by Lord John Manners, the Postmaster-General, of the report of the committee appointed to investigate the cause of the stated "increased cost of the telegraph service since the acquisition of the telegraphs by the State," has now been issued, and will no doubt be read with satisfaction by all classes of the community.

Referring to the discrepancies between the estimates and expenditure in past years, his lordship readily admits that no good purpose would be obtained by again referring to them. He has, however, every reason to hope that the difficulties inseparable from the first years of a new service have now been surmounted, and that the recurrence of such discrepancies will for the future be impossible. In confirmation of which he refers to the fact that the expenditure for the past financial year, 1874-5, has been kept well within the limits of the Parliamentary grant. Dealing with the assertion that to increase of salaries is due the first and obvious cause of the great and increasing charges, his lordship defends the course taken by the department as due: first, to the fact that the pay of all the companies' servants had been kept down in view of the coming transfer, secondly, that there was a general rise in wages throughout the country in the interval between 1868 and 1872, and thirdly, that it was but fair to those officers who took service with the Government to place them on a footing with others holding equally onerous positions.

Coming to the question of the increased cost of supervision, his lordship makes no doubt that now the new works of the Department are complete, a considerable saving can be effected in the engineering branch; whilst with regard to the cost of the secretarial staff he proceeds: "I apprehend that secretarial management under the Post Office will contrast not unfavourably with the management under the companies. For while the private companies were supervised by nine secretaries and assistant secretaries and 53 directors, supervision in the secretary's office of the Post Office has been mainly effected by a secretary and two principal clerks, with assistants. The companies dealt with rather more than 6,000,000 messages per annum, and paid £15,000 a year to secretaries, directors, and secretaries' clerks, numbering 86; the Post Office deals with 20,000,000 messages, and delivers 222,000,000 words of news, and pays only £16,900 a year as the cost of that part of the secretary's office which supervises telegraphy, and which comprises 88 persons;" and with regard to the staff of the account branch, "It appears that the companies found that the services of 69 people were required, at an annual cost of £8,000, or £118 a head, to check the accounts of about 6,500,000 messages, and press work described as "trifling." The Post Office employs 292 persons, at an annual cost of £103 per head, representing £30,000 a year, to check about 20,000,000 messages and 222,000,000 words of news. It does not seem to me, therefore, that the view adopted by the committee rests upon any foundation."

It is added that in the Secretary's office reductions have already been effected, and that the introduction of telegraph stamps will enable similar reductions to be effected in the Receiver and Accountant General's department.

Touching the question of charging expenditure to capital, tabular statements are submitted, showing that, if due allowance be made for the expenditure properly chargeable to capital, the proportion of working expenses for the year 1874-75, instead of 96.6 per cent., as the Committee allege, more nearly approaches 75 per cent. Referring to the amended general estimate of revenue and expenditure for 1875-6, put forward by the Committee, and which showed a deficiency of £268,524, Lord John Manners submits a statement, which he regards as more correct, and which reduces the deficiency to £137,434, and here his Lordship remarks:—

"I am quite prepared to admit that a deficiency to any extent is unsatisfactory; but I contend, and in this I conceive that I am fully borne out by the whole spirit of the report of the Committee, that

whilst the department cannot claim to have been infallible in its management, the deficiency is mainly due to the exorbitant price paid for many of the telegraph undertakings, and to the heavy quantity of unremunerative labour, which it is compelled by statute to perform. I would, at the same time, remind your lordships that although up to the 31st of December, 1874, the deficiency of telegraph revenue to meet the interest on the stock issued under the authority of the Telegraph Acts, 1869, 1871, and 1873, amounted to the sum of £473,152 3s. 4d., yet, that if from this sum is deducted £220,386, the amount of the payments for wayleaves, extensions, and pensions properly chargeable to capital, the deficiency of the telegraph revenue, after allowing interest upon the sum deducted, to meet the interest due, is under £270,000, or less than £54,000 per annum for each of the five years since the transfer."

With reference to the number of non-paying offices, it is stated these have entirely disappeared in London, and diminished altogether to the extent of one-half since the return was taken in 1874. In the face of such facts, his lordship hesitates to recommend the withdrawal of accommodation already enjoyed by the public.

The recommendation to amalgamate the duties of the Post-office Surveyor with those of the Divisional Engineer is regarded as likely, if carried into effect, to be attended with injury to both branches of the service; whilst as regards the proposal to extend the employment of the Royal Engineers, the review continues:—

"The employment of the Royal Engineers, to which the committee next advert, is a political rather than a departmental question, but I can deal with it here in regard only to its financial bearing. The engineering staff admits of reductions; but this can only be accomplished as opportunities occur.

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The Royal Engineers can at any time return to the War Office; and, as all that would be required to replace them would be a few additional line men, nearly two-thirds of their allowances, or about £2,500 a year, would be saved. This being so, I am compelled to advocate their withdrawal, as, at a time when it is thought necessary by the Committee, on financial grounds, to recommend a diminution of public accommodation, it is manifestly wrong to expend so large a sum annually on an object altogether foreign to that for which the purchase of the telegraphs by the State was undertaken. In the event, however, of its being considered desirable, upon grounds of Imperial policy, that the postal telegraph service should be used as a school of instruction in telegraphy for the Royal Engineers, it will be but just that the pay of the officers and men thus instructed should fall, not on telegraph, but on War Office funds."

His lordship does not think any attempt by legislation or otherwise to induce railway companies to undertake the maintenance of the lines off the railways would be successful, and doubts whether the Committee could be in earnest in making such a proposition. He demurs to the assertion that the working expenses have increased in a greater ratio than the increase of messages; so far from this the net revenue now exhibits an increase considerably larger than the increase of messages, a fact which induces a hope that the undertaking will ere long exhibit a profitable result, provided that the capital account is charged with the expenditure which properly belongs to it, instead of being a charge against revenue.

Touching the question of tariff, his lordship remarks, that in acquiring the telegraphs, the intention of the legislature was to consult public convenience, and not to transform the transaction into a mere commercial speculation, and he adds, "it would in my opinion, be inexpedient and hardly "fair, to go back entirely from what parliament granted when the Telegraph Bill was passed." The existing press rates will therefore continue except as regards the "copy" charge of 2d, which it is proposed shall apply only in cases where such copies can be delivered by hand. If this has effect, it is estimated to produce a net gain of revenue of not less than £30,000 a year. Modifications in the charges for messages handed in at railway stations, the commission on which as now paid by the department varies from 3d. to 9d. on the message, are also advocated, and valued at £12,000. A late and Sunday fee of 6d, except on press messages, to which it is not to apply, is also calculated to produce a like sum of £12,000 per annum, and it is lastly proposed to purchase up the rights possessed by certain railway companies to send free messages over the wires of the Department: the main object of which is to free the wires for other and more profitable work, and relieve the department of much correspondence.

His lordship concludes:—

"The charge is that the telegraphs in the hands of the Post Office have not turned out a paying concern. Had the increase in the number of telegraph offices from 2,488 to 5,600, and the increase in the number of messages from 6,000,000 to 20,000,000 been accompanied by a corresponding increase of net revenue, it would have been highly satisfactory; but there is nothing in the Act of 1868 to show that this was expected, nor indeed would it have been reasonable to expect it. What the legislature did intend was that the public should be better accommodated, and during all the discussions which have taken place in Parliament, or elsewhere, no complaint that this intention has not been carried out, so far as I am aware, ever been heard. Undoubtedly, and mainly for reasons which are acknowledged by the committee, the financial result of the measure is not, up to the present, satisfactory. There are, however, signs of improvement; the service is yet but in its infancy; the business of the department is steadily increasing, and the necessity for economical management will be steadily kept in view. If the alterations which I have proposed be adopted, and due allowance be made for the charge upon revenue of expenditure fairly chargeable to capital in ordinary commercial undertakings, I shall be much disappointed if, at the expiration of the ensuing financial year, telegraph receipts, as compared with working expenses, do not show a result which would make it impossible to ask parliament to adopt the retrograde policy which the committee have felt it their duty to advocate."

The receipts of the Western and Brazilian Telegraph Company for four weeks ending 25th inst. show £2,501 increase over same period of 1875.

BLOCK SIGNALLING.

Continued from p. 56.

PURSUING the description of the mode of signalling a train by the instruments last described, it will assist the reader if he has before him the diagram given in the last number, at page 55.

The warning signal having been sent, is acknowledged by the distant station pressing his bell-key once, and so ringing the bell one stroke at the station from which the warning signal was sent.

The semaphore arm for up trains standing at clear, the train is allowed to proceed, and on doing so its departure is signalled by, say—

If a passenger train	2 beats.
If an express train	4 „
If a ballast train	5 „

This is done by pressing the bell-key a corresponding number of times, the beats being given with a uniform interval of time between each. The station to which the train is proceeding now has the information that it has left the station immediately in the rear of him, and it is necessary for the protection of the train that no other train shall follow it until it has arrived at his station. To effect this, he raises the semaphore arm at the station which the train has just left. He does this by placing his switch handle P (fig. 17) at ON—that is, in contact with the arc Q. The line-wire connecting the semaphore (fig. 17) with the switch at the distant station is now free from any current, and the armature E being released from its influence of the magnet H, falls away from the poles by the influence of the weight W, fixed on the lever D W, which then assumes its position of rest on the contact F. No current is now flowing on the line-wire or through the coils H, and so long as this is so, the arm of the semaphore will, under the influence of the weight W, stand at danger. The switch at the station to which the train is proceeding remains at the will of the operator in the position last placed by the pressure of the spring below the lever handle.

The raising of the arm is the acknowledgment to the departure signal. It is now necesary that the station at which the arm has been raised should acknowledge it, and at the same time satisfy the corresponding station that the arm *has* been raised, and consequently that the line is blocked in the rear of the train. He presses his bell-key *once*, which rings the bell at the corresponding station once; but in doing this he no longer transmits the same current as that employed by him when sending the warning and departure signals. Since, then, the arm of his electric semaphore has been raised from the depressed, or all clear, position to that indicating danger, and the lever D W, instead of, as formerly, resting on the contact G, now rests on F, and instead of our having a positive current in circuit with the lower stud B, of the bell-key, we have now a zinc current brought up to it, and on pressing the lever A of the bell-key, we are sending a zinc current on the bell-wire to the distant station. Here it enters by the lever of the bell-key, and through the upper stud C, passes on to the bell coils E, and so to earth. Between the poles of the coils E, is a magnet fixed on the spindle N, carrying a shield with the words OFF, ON. A zinc current passing through these coils places this magnet in such a position that the word ON is brought up to the aperture in the face of the bell, which then reads, "Down signal on at ——" (the station with which the bell communicates). So in this case the bell at the distant station is made to indicate that the up signal is *on* at the station which the train has just left.

The train now travels through the section till it arrives at the station to which it has been signalled. The arrival there is announced by the lowering of the arm, and an "all clear" signal on the bell at the station which it last left, and at which point the up road stands blocked against all following trains. To do this the switch handle P, is now drawn over to OFF in contact with the arc R. A current now flows from the switch along the line wire to the semaphore, passes through the coils H, and attracting the armature E, overcomes the influence of the weight W, and lowers the arm to the all clear position. At the same time the bell-key is pressed—say three times—to indicate by sound that the line is clear. The receiving station now acknowledges this, but here again the lever D W, of the semaphore has changed, and now a copper current comes up to the bell-key which carries the bell indicator at the distant station over to OFF, and the bell there then reads "up signal OFF at——."

This completes the operation. The instruments are again restored to their normal condition, and the section being clear, another train may follow that just signalled out.

The points to be noticed are, first, the automatic action of the current actuating the bell by which the signalman, who works by the aid of his switch, the block signal miles away, is informed of the position of the arm of that signal. He knows if the bell indicator is carried over from OFF to ON, or *vice versa*, that the arm has moved in a corresponding manner. He is assured of the due and faithful action of his signals. He has no power over his bell indicator; he knows its action depends upon the semaphore. Secondly, the important fact that any rupture of the wires would place the signals at danger. Thirdly, that atmospheric electricity has no effect on the signals sufficient to change their character or reverse them—for the semaphore wire being direct to earth when the switch is ON, the resistance of the circuit in that direction is so little in comparison with the coils that all its intensity would go in that direction, whilst, should the wire be struck at a moment when the switch stands to OFF the current would merely tend to hold the arm the more firmly in the position required. And thirdly, that the indicating signals—semaphore and bell—are workable only from the distant stations, and wholly beyond the control of the receiver.

THE MAGNETIC EQUIVALENT OF HEAT.

ONE of the most remarkable of recent advances in Physics, is the elucidation of the relation between heat, electricity, and mechanical work. The first important step in this direction was the discovery of the equivalent of heat, and the *vis viva* of a moving body. Afterwards came the discovery of the equivalence of heat and electricity, both of the Leyden and the voltaic battery.

It was natural to suppose that magnetism would present phenomena and laws similar to those of the other physical forces. Since, according to Ampere's theory, electricity is to be regarded as the cause of magnetism, it might be hoped that magetic phenomena also could be brought into the domain of thermodynamics by an extension of the laws of electricity. The writings of Thomson and Helmholtz contain some consideration of thermodynamic theory to magnetism. It is to MM. Lamin and Roger however, that we owe the first decisive experiment, establishing the production of heat through disappearance of magnetism. The soft iron of an electro-magnet having been placed in the reservoir of a large thermometer of oil of turpentine, an interrupted current was sent through the spiral, and it was observed that the liquid expanded. It is probable, says the experimenter, "that during each magnetisation, a part of the electricity goes into the iron, here producing magnetism, and that at the moment of demagnetisation, this magnetism is transformed into heat."

This formed the starting point of a recent investigation of the whole subject by M. Cazin, (described in the *Annales de Chimie et de Physique* for December, 1875).

The first experiments he made were to demonstrate the production of heat by magnetism, and he used three methods. In the first, the iron core was enclosed in a hermetically closed vessel which was filled with petroleum oil and surrounded by the magnetising spiral. From the vessel proceeded a capillary tube also containing petroleum oil, and the charges of level in it were observed when the iron core was magnetised by an interrupted current. If heat were produced by the magnetism, the petroleum oil must expand and the level in the capillary tube be considerably displaced. Before and after each magnetising of the core, the state of the petroleum oil thermometer was observed for some time, was to determine the thermal influence of the surroundings and eliminate these from the experiment. As it was possible, however that the displacement of level might arise, not from a heat action, but from the expansion of the iron produced by magnetism, the following experiment was arranged. Into the vessel containing the liquid and the iron core, wasintroduced some closed glass tubes, which displaced a third of the liquid; the vessel was then closed, and the experiment repeated. If the expansion of the iron were the cause of the change of level, this must now be the same as in the experiment without the glass tubes; if, on the other hand, the change of the level were due to the heat produced, it must now be different, for instead of three volumes of liquid, two volumes of liquid, and one volume of glass were heated by the same quantity of heat. The experiment then revealed a difference, which corresponded to the difference of the specific heats and confinements of expansion of petroleum-oil and glass. It was thus proved, that the discontinuous magnetisation of an iron core produces heat.

In another method for demonstration and measurement of this heat effect, the core consisted of an iron tube closed at both ends with corks, and enclosing the bulb of an ordinary thermometer; which showed a heat-action when the spiral was traversed by an interrupted current. In the third method a differential thermometer was used, consisting of two hollow iron cores, communicating together by a capillary tube in which was a liquid index; every heat-action in the one core was followed by an expansion of the contained air, and displacement of the index.

The heat effect of magnetism being thus susceptible of proof and measurement, the magnetism produced in each experiment were determined by exact methods, both the amount and the moment; and the time was determined which might elapse between each interruption and closing of the magnetic circuit, without the entire action being prejudiced.

Experimenting with a bipolar tube-shaped core M. Cazin first varied the quantity of the magnetism produced, and arrived at the following law:—"When the intensity of the current in the wire of an electric-magnet is varied the quantities of heat produced by the interruptions of the current are proportional to the square of the quantities of magnetism alternately gained and lost by the core."

In a second series of experiments, the interval between the two poles was introduced as the only variable factor. This was done by means of two iron cores of different form, which took equal magnetisms under the influence of equal currents. The measurement of the quantity of heat which these two magnets produced, led to the following law:—"When the current develops equal quantities of magnetism in different magnets, the quantities of heat arising from interruption of the current are proportional to the intervals between the poles."

These two experience laws may be comprehended in the following more general law:—"When an interrupted current is allowed to flow through a straight electro-magnet, and the dimensions of the core, the number of turns of the wire, and the intensity of the current are varied, then the quantities of heat produced in the core are proportional to the product of the square of the quantity of magnetism into the interval between the poles,"

Experiments were further made with tube-shaped cores, in which, by means of a series of coils pushed over them, several magnetic poles were produced simultaneously. Here the heat measurements gave the following law:—"When straight iron core is surrounded by a series of similar coils, when the current flows in alternately opposite directions, and when these coils produce poles at equal distances from each other, the quantitities of heat which are produced in the core by the same interrupted current are inversely proportional to the squares of the number of intervals."

In the foregoing experiments heat was developed in the core, while a regularly interrupted current produced in this core a series of magnetisations and demagnetisations. M. Cazin now sought to determine the cause of the development of heat, and proceeded as follows:—Round the iron core in the petroleum thermometer two coils of 480 turns were passed, one of them being in the interrupted magnetising circuit, while the other formed a special circuit, which at each turn of the interrupting apparatus was closed. The first coil could

now induce a current in the second, if the closures of the two circuits took place at the proper times, as might be arranged at will. These experiments gave the greatest development of heat when the circuit of the second spiral remained continually open. The heat was not altered when the circuit was closed at closing of the magnetising current. There is thus no thermal action during the variable period of closure. Lastly, the heat was smaller when the circuit of the second spiral, during the opening of the inducing circuit, was closed; it went down as much as the half. "It thus proved that the production of the magnetic heat takes place during the opening of the voltaic circuit, consequently, that it accompanies the disappearance of magnetism in the core."

The decrease of heat in this last case is explained on the principles of themodynamics. The disappearance of the magnetism is the cause of the appearance of a certain quantity of heat. When no circuit is near, in which an induced current can arise, then the whole of this heat appears in the core; when, however, induction occurs, a part of the heat appears in the induced circuit, and the rest remains in the core. The cessation of the magnetisation is an operation in which the magnetic energy decreases, and is transformed into heat energy, either in the core, or in neighbouring masses, which are in a position to be the seat of induction-phenomena. This is a new example of the transformation of energy.

It is known that in electro-magnets such induction always occurs at opening of the magnetising current, appearing as the extra current at opening. Thereby a part of the heat which is produced through disappearance of the magnetism is always lost. M. Cazin, therefore, made a series of special experiments; in which he varied the extra current in order to determine the consequent modifications of the relation of heat to magnetism. The result was, that to obtain a probable value for the magnetic equivalent of heat, we must diminish the induction action of the spiral upon itself as much as possible, employing a thick wire and a small number of turns; also we must make the duration of the spark at opening as short as possible.

As a general result of the investigation, the following proposition was arrived at:—"The disappearance of magnetism in the core of a bipolar electro-magnet is accompanied by the production of a quantity of heat which is propoportional to the distance between the poles, and the square of the quantity of temporary magnetism which the core takes when the circuit is closed." If we denote the quantity of heat by Q, the quantity of magnetism by m, and the interval between the pole by l, then we have for a given iron core the equation $A\,Q = m^2 l$. Dividing $m^2 l$ by Q, we have an approximate view of the magnetic equivalent of heat, namely, of the quantity of magnetic energy that is equivalent to a heat unit. Taking into account all the data furnished by his previous expertments, M. Cazin made two series of determinations; in one case he produced the interruption spark in air, and thereby obtained $A = 110{,}400{,}000$; in the other case the spark was made to pass in ether, and he got the value 106,000,000. "The second of these numbers," he says, "is nearer truth than the first, as the duration of the interruption spark, corresponding to it, was much shorter; but it is still somewhat too great, as the extra current at opening is not nil. I believe, therefore, that the exact number for the equivalent sought is not far from 100,000,000."

THE BAKERIAN LECTURE.

An Account of several new Instruments and Processes for determining the Constants of a Voltaic Circuit.

By CHARLES WHEATSTONE, Esq., F.R.S.,
Professor of Experimental Philosophy in King's College, London, Corresponding Member of the Academy of Sciences at Paris, &c.

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(Continued from page 42)

SECTION 14.—*Instrument for Measuring the Resistance of Liquids.*—We do not at present possess any accurate measures of the conductabilities of liquids, nor have there yet been formed any tables which show the even real order of their conducting powers. In the experiments having this object in view which have hitherto been made, the contrary electro-motive force, which generally arises when the electric current passes through a liquid capable of undergoing decomposition (Section 11, 4), has been left entirely out of consideration, and the results therefore have widely deviated from the truth. By the simple instrument represented at fig. 4, I have been able to eliminate completely

Fig. 4

this source of error, and to obtain perfectly constant results. A is a glass tube about two inches long and half an inch in internal diameter; a portion of the tube is ground away for an inch and a quarter of its length, so as to leave a segment of 270°; at one extremity of this aperture is fixed a metal plug terminated by a platinum plate, and at the other end is a moveable piston, terminated also by a plate of platinum, capable of being advanced to within a quarter of an inch from the fixed plate; the range of its motion is thus limited to one inch, and an attached micrometric apparatus enables any portion of this distance to be accurately measured. To obtain the measure of the resistance of a liquid, I proceed in the following way;—I interpose in the circuit a small constant battery, consisting of about three elements, with the rheostat, the resistance-coils, the galvanometer, and the measuring tube just described. The end of the piston being a quarter of an inch distant from the fixed plate, I fill the intervening space with the liquid, the resistance of which is to be measured. I then adjust the rheostat to bring the needle of the galvanometer to a determined point; this having been noted, I draw the piston back through the entire remaining space of one inch, and fill the vacancy with the same liquid; the needle will recede towards zero. I then diminish the resistance of the circuit by means of the rheostat and the resistance-coils, until the needle stands at the same point that it did when only a

quarter of an inch of the liquid column was interposed. The reduced length of the wire thus taken out of the circuit will be the measure of the resistance of one inch of the liquid. The contrary electro-motive force arising from the decomposition of the liquid exists in the circuit during the whole process, and therefore does not affect the result.

The measure of the resistance of a liquid must be made immediately after it is placed in the circuit, because if a current be allowed to act upon it for any length of time the nature of the solution changes. In the case of sulphuric acid, for instance, the solution is rendered stronger by the decomposition and consequent diminution of the water, while, in the case of a metallic salt, not only is the water decomposed, but the metal is reduced, and free acid is liberated. Under the conditions, however, of my experiments, the chemical action is so slow, and the time of operation is so short, that no sensible changes of this kind take place.

The resistance of liquids to the transmission of electricity is, no doubt, one of their most important physical properties. An investigation of all the circumstances which occasion changes in this property, especially if accompanied with accurate quantitative determinations, must necessarily lead to important and hitherto unobserved relations. To investigate the changes due to different degrees of dilution and temperature alone will be a task requiring considerable patience. I have made many measures of the specific resistances of different conducting liquids, by the aid of the preceding process, but as they have not been sufficiently numerous to enable any general conclusions to be drawn, and as I am at present engaged in a more extensive series of experiments in which strict attention will be paid to all the known influencing circumstances, I shall defer an account of them to a future occasion.

As bodies differ so much from each other in their specific resistances, and as the means of determining this property are so easy, it cannot be doubted that hereafter this process will be extensively employed to detect the purity of substances and to distinguish them from each other.

Another method of measuring the resistance of a conducting liquid is the following:—Prepare a circuit the electro-motive force and resistance of which is known,

$$\frac{E}{R} = F.$$

Interpose the liquid which is to be the subject of experiment in a small cell with two parallel platinum electrodes; the expression for the circuit will then be

$$\frac{E - e}{R + x} = F';$$

e being the contrary electro-motive force, and x the resistance of the liquid which is to be determined. Having ascertained the value of e by the process described in section 10, subtract, by means of the rheostat and coils, a resistance which shall make the force again equal to F; the expression will then become

$$\frac{E - e}{R + x - \lambda} = \frac{E}{R'}$$

whence—

$$x = \lambda - \frac{e}{E} R.$$

Therefore the resistance x of the liquid is equal to the resistance λ taken out of the circuit by the rheostat, minus the total resistance of the original circuit multiplied by the ratio

$$\frac{e}{E}.$$

Section 15.—When a galvanometer is employed to measure the force of a current its wire is usually interposed in the circuit. But it is impossible, in this way, to make use of the same galvanometer to measure the force of the current in circuits of different kinds. A galvanometer with numerous coils of thin wire adds a very considerable resistance to a circuit in which the electro-motive force is great and the resistance small; while, on the other hand, a galvanometer with a short thick wire will give scarcely any indication in a circuit in which the resistance is very great, though the electro-motive force may be considerable. Besides, a delicate galvanometer is incapable of indicating energetic forces.

But by the following simple means the same delicate galvanometer may be employed to measure forces of every degree of energy, and in all kinds of circuits, without introducing any inconvenient resistance into them.

If the current be caused to pass simultaneously through two paths, one being the wire of the galvanometer, and the other another wire connected with its two ends, the current will be divided in the inverse proportion of the resistances of the two paths. The action upon the needle of the galvanometer may hereby, by employing different wires to divert a portion of the current, be reduced to any degree. If the proportionate forces are known for the galvanometer without the reducing wire, they will remain equally proportionate whatever the resistance of the latter may be; but measures made with the same instrument, with different reducing wires applied, will not be comparable unless the changed resistance of the galvanometer thus modified be taken into account.

But strictly comparable measures may be obtained, if the precaution be taken of adding, to the principal portion of the circuit, a resistance which will compensate for the diminution of resistance occasioned by placing the reducing wire. Let g be the reduced length of the galvanometer wire, and $n\,g$ that of the reducing wire. The force of the current in the principal portion of the circuit will be to that in the galvanometer wire as

$$1 : \frac{n}{n+1}.$$

The resistance to be added to the principal portion of the circuit, in order to maintain the current the same as when no reducing wire is added, is

$$\frac{g}{n+1}.$$

When the measures of energetic currents are required to be determined by means of a delicate galvanometer, it is sufficient to attach its two ends

to two points of the conducting wire.* The distance between these points must remain the same in all comparative experiments, but the absolute deviations of the needle will be greater as these points are further from each other. In the case of the circuit of a powerful electro-magnetic engine, or of a volta-typing apparatus, the diminution of resistance occasioned by connecting the galvanometer wire in the manner above described is so trifling that it would be useless to take it into account, and the compensation above alluded to is, therefore, unnecessary.

(To be Continued.)

* Professor Petrina of Linz has proposed (Poggendorff's "Annalen," vol. lxii. 1842, No. 9) a similar means of measuring and comparing electric currents of every degree of force. He interposes in the circuit a canal of mercury, the section of which is four square lines, and plunges into it, at various distances from each other, the ends of the wire of a sensitive galvanometer. He shows that if the resistance in the galvanometer wire be very considerable, and that of the mercury in the canal be small in comparison, the force acting on the galvanometer needle will be sensibly proportional to the distance between the ends of the wire, and he has founded on this principle a ready approximative method of graduating the galvanometer.

Notes.

A GENERAL MEETING of the Universal Private Telegraph Company (Limited) will be held on the 9th of March to receive the accounts of the liquidators.

On Wednesday, the 23rd February, at an adjourned meeting of the Western and Brazilian Telegraph Company, the accounts for the year ending 30th September last were adopted.

The telegraph steamship *International* left the Thames on the 12th inst. to repair the Santander Cable of the Direct Spanish Telegraph Company (Limited), which was interrupted near the Spanish coast in shallow water. The cable is now in working order.

The Western and Brazilian Company's Pernambuco-Para Cable having been repaired, the telegrams for Paris are accepted as usual by the Eastern Telegraph Company (Limited).

The Eastern Extension, Australasia, and China Telegraph Company (Limited) announce that the cable between Sydney and New Zealand has been successfully laid by the Telegraph Construction and Maintenance Company (Limited).

The ordinary general meeting of Hooper's Telegraph Works Company (Limited) was held on the 24th instant at the City Terminus Hotel, Cannon-street; Mr. Frederick Lubbock presiding. The Chairman said the arrangements come to a few weeks before with reference to debentures and debt to Mr. Hooper had been carried out. The trustees had also realised the trust fund, and it had been distributed. They were not able to announce any new business, but some large contracts were under negociation, which they were sanguine would lead to satisfactory results. There had been a verdict given against the company in a suit brought for commission on behalf of the late Mr. Stock, but they had appealed against it, and advised on the best authority that it would be reversed. The debtor balance of £52,554 had arisen from a depreciation in securities, but as there was no intention of realising them at present, there were hopes they would improve in value. £5,000 had been written off the works and machinery account for depreciation. This was following up a practice that had always been adopted, as during the last six years they had written off a total of £90,902 from the value of their works and ships, and they had every reason to believe they were worth now as much as they were valued at. The only other question on which he would touch was that of the contract with the Central American Company, which he was sorry to say the latter had not fulfilled, and they had consequently been obliged to commence legal proceedings against them. He concluded by moving the adoption of the report. Colonel the Hon. W. Fielding, in seconding this, said he wished to deny personally one or two statements that had been in circulation. The first was that there was any discord on the board; the second was that Mr. Hooper had not behaved well to the company; and the third was that there was an intention to wind it up. He passed a high encomium on the assistance he had received from both Mr. Hooper and his son, who had put themselves to considerable straits to assist them. There was work to be done, and he personally would never give his vote to a winding-up order. Mr. Hancock, in a long speech, reviewed the position of the company, and insisted that the accounts should only be received subject to rectification with Mr. Hooper with reference to the claim of Mr. Stock for £23,000. This amount should have appeared in its proper place in the previous balance-sheets, and, if they had to pay it, Mr. Hooper ought to pay one-half. He moved an amendment to the effect that the report be received and adopted, subject to re-arrangement. Mr. Abbott seconded the amendment.—Several other shareholders addressed the meeting and the Chairman, after replying to some questions that had been put in the course of the discussion, put the amendment, which was negatived, and the original motion was carried with four dissentients.

McLean's Telegraphic Agency announce the opening up of their system for sending private dispatches of one word and upwards to New Zealand. The cables between Sydney and New Zealand is working well, cablegrams from Wellington, New Zealand, dated noon February 23rd,

having reached London at 11.15 a.m. on the 24th inst.

The report of the Submarine Telegraph Company (Limited) states that the accounts for the past half-year, ending 31st December last, show a nett increase of £3,167 over the corresponding half-year of 1874, which enables a dividend at the rate of 17½ per cent. per annum to be recommended; and carrying over a balance of £826 to the next account. The number of messages that passed over the lines worked by the Company during the six months ending 31st December last was 780,924, being the greatest number that has ever been transmitted in any half-year during the Company's existence, which is a satisfactory proof of the steady improvement of telegraphic intercourse with the Continent. The principal portion of this increase arises from the establishment of the direct service with the Paris Bourse, and the additional facilities which have thus been afforded to members of the Stock Exchange and merchants transacting business with Paris. The rental of special wires to the Press has also been a source of additional revenue to the Company.

The report of the Telegraph Construction and Maintenance Company (Limited) was issued to the meeting on the 29th inst. The net profit for the year is stated at £10,237, after charging the interest on the debentures. With the sum of £114,351 brought forward from the previous year, there is a total of £124,589. From this is deducted the interim dividend of 5 per cent., amounting to £22,410, leaving 102,179, available for a proposed dividend of 10 per cent, or £44,820 (being at the rate of £1 4s. per share, and making a total dividend for the year of 15 per cent.), carrying forward £57,000.

The Eastern Telegraph Company (Limited) announce that the New Zealand Cable being open for traffic, messages for New Zealand can now be sent direct by telegraph from the offices of that company, 74, Old Broad-street, or 8 Leadenhalll street. They will also be received at any postastation if directed "via Eastern" or "via Falmouth."

The roll of the Institution of Civil Engineers on the 1st of this month contained the names of 843 members, 1,530 associates, and 14 honorary members, while there were also attached 373 students, making a total of 2,760 of all ranks.

Last week, Colonel Sandford, R.A., Executive Commissioner of the International Exhibition, Philadelphia, sailed from Liverpool in the American Liner *Indiana*, to join his colleague, Professor Archer, in Philadelphia. Colonel Sandford is accompanied by Mr. Hodgkinson (Finance), Mr. Ernest Charrington (Correspondence), Mr. Brett (India), and 15 non-commissioned officers and men of the Royal Engineers and metropolitan police force. Mr. Trendell, Secretary to the Commissioners, will remain in charge of the office, 5, Craig's-court, Charing-cross, till April, and those exhibitors who have not yet applied for Customs certificates and labels are requested to do so at least a week before their consignments are ready for despatch.

From the Journal of Applied Science we gather the following: "The produce market of Arecata has, ever since July, 1874, been furnished with considerable quantities of indiarubber; the exports in 1874 amounted to 265 bales of 170 pounds each, chiefly sent to Ceara and Pernambuco for shipment. It is the produce of *Hanrornia speciosa*. If the people of the interior, where the milk of the mangabeira is collected, knew how to prepare the rubber properly from the juice or milk, no doubt the newly-discovered material would soon be followed by improvement. It fetches a far higher price than any other native produce brought to market, as much as 900 reis per kilo being paid for good and dry qualities. The country where it is gathered and prepared is about 100 English miles distant, and the trees cover a hilly district of 36 leagues long by about 4 leagues broad.

Mr. Schwendler, the Electrician to the Government Telegraph Department of India, has introduced on the direct line between Bombay and Calcutta a method of simultaneous telegraphic communication, founded on his duplex system, which is said to have worked so well during the rainy season that the Government have determined to bring it into general use.

The report issued by the Telegraph Construction Company states:—"The work carried out by the company during the year has comprised the laying of a cable 45 miles in length for the South Australian Government, connecting Kangaroo Island with the mainland of that colony, and a line of 1,370 miles in length between New South Wales and New Zealand. The contract for the latter was entered into with the Eastern Extension Telegraph Company on the 30th July last. The cable was manufactured during the year, and has since been successfully laid. A contract has been entered into with the Eastern Telegraph Company for duplicating the cables between Suez, Aden, and Bombay, and negotiations are in progress with the Eastern Extension Telegraph Company for laying a new line in the Bay of Bengal, between Rangoon and Penang. The project alluded to in the last two annual reports for connecting Peru

with Panama, on the Pacific coast, by a submarine cable, has, after protracted negotiations, been abandoned by mutual consent, it having been found impracticable to obtain the necessary landing rights at Panama, except on terms which the Company could not with advantage accept. The working agreement that existed between this Company and Mr. Henley, of North Woolwich, and which lapsed through the suspension of Mr. Henley, has been renewed with a Company formed for the purpose of carrying on his extensive works, on terms which, it is believed, will be advantageous to both parties."

CHINA.

SHORTLY after the establishment of the Torpedo College at Foochow, His Excellency Li Hung Chang, Viceroy of Cheli, First Guardian of the Emperor, &c., &c., sent an official request that Mr. J. A. Betts, the director of the college, should proceed to Tientsin with the whole of the torpedo apparatus just received from England, to carry out a series of experiments before His Excellency.

The *Chi-Ngan*, one of the Chinese gunboats, was ordered to convey Mr. Betts, and the stores, to the latter port, and during the month of October last a lengthened and very successful series of experiments in telegraphy and torpedo warfare were carried out in His Excellency's presence.

Telegraphic circuits were established, and a complete system of torpedo defence fully illustrated by the explosion of numerous torpedoes in the Pei-ho, near Tientsin. Further experiments with heavy charges were shown at the Takn Forts. His excellency lent his own steam launch for these trials, and expressed himself much pleased. The electro-contact torpedoes excited great interest and were much admired.

Mr. Betts exhibited the Royal Engineers' system of telegraphing by "Walker's Lime-light" on the city walls of Tientsin; this seemed to create a deal of astonishment among the Chinese, and although at a late hour of the night, and bitterly cold, caused an immense crowd to assemble.

Mr. Betts will return to Tientsin in the spring, when he will at once commence drawing up a system of torpedo defence for the Takn and Peh-tung Forts, which are also to be connected by a line of telegraphs.

M. Duchemin has found that nickel, deposited by electricity on the magnets of compasses, preserves them from oxidation. He deposited in this way a layer of nickel on several rings of one of his circular compasses, keeping two concentric circles free from the operation This compass was put on board a vessel which went round the world. The rings covered with nickel preserved their polish, but the others were completely rusty. The magnetic power of the nickelized rings had been exerted with difficulty, no doubt on account of the magnetic property of the nickel. — *Comptes Rendus de l'Academie des Sciences, Nov.* 15, 1875.

Proceedings of Societies.

THE SOCIETY OF TELEGRAPH ENGINEERS.

Contributions to the Theory of Submerging and Testing Submarine Telegraphs.
By Dr. WERNER SIEMENS.

THE starting point of submarine telegraphy is to be found in the subterranean lines constructed in Prussia during the years 1847—1852. Before that time, it is true, attempts had been made to insulate wires with glass tubes, caoutchouc, &c., for use as underground lines. Experiments on a somewhat extensive scale by Jacobi* at St. Petersburg in the year 1842 deserve mention; but these attempts failed.

In the year 1846 the author suggested to the Prussian government the use of gutta-percha as insulating material, this gum having then recently become known in Europe. Its remarkable plasticity and insulating property appeared to render it very suitable to the purpose in question, but neither the experiments made at Berlin, nor those carried out simultaneously in England, were attended with satisfactory results; for the joints of the gutta-percha (which was rolled round the wire), gave way after a short time. At last, in the year 1847, the problem found its solution in a covering machine, constructed and used by the author and Mr. Halske, by means of which the gutta-percha, rendered plastic by heat, is pressed round the wire without any seaming.

During the subsequent years an extensive network of underground lines, insulated with gutta-percha pressed round the conducting wires, was somewhat too hastily and inconsiderately introduced in North Germany and Russia; although those lines were far from durable (particularly because the conducting wires, to save expense, were imbedded in the ground without external protection, and at too small a depth), they afforded opportunity of gaining practical knowledge for the construction and maintenance of such insulated conductors, and of studying their physical properties. But it was reserved for English enterprise to convert the knowledge and experience thus gained to practical account in a sphere where there was no competition with cheaper overground lines, that is to say, to submarine telegraphy.

As early as 1850, Mr. Brett laid a single gutta-percha-covered copper wire across the Channel between Dover and Calais. As might be expected, this became useless; but in 1851, Mr. Brett substituted a conducting wire insulated with gutta-percha, and protected externally by a sheathing of iron wires. This was the first practical submarine cable.

No great difficulties were encountered in laying these cables in the comparatively shallow waters of the Channel. But when later Mr. Brett endeavoured to lay such cables in seas of greater depth he failed, because the forces brought into play in laying deep sea cables were not yet recognised, and, consequently, the necessary precautions had not been taken. The laying of the first successful deep sea cable between Cagliari and Bona, in the year 1857, in which the author

* *Pogg. Annalen*, vol. xxviii. p. 403.

had been requested to take part, led him to investigate the mechanical principles of cable-laying.

As is the practice in England, the cable is stored in water-tanks on board the cable-ship, where it is coiled in a continuous spiral, and whence it is uncoiled, without kinking or being otherwise impeded, over a pulley fixed above the middle of the tank. If we suppose the vessel to progress continuously with uniform speed in a straight line, letting the cable drop from her stern—the great length of the suspended cable admitting of our regarding it as perfectly flexible—every part of the cable will sink to the bottom of the sea with equal and constant velocity. Therefore, the distance of any part of the sinking cable from the surface of the water must be in proportion to the time that elapses from its leaving the ship. If the speed of the ship be constant, this time will be proportional to the horizontal distance of the ship, and the cable must form a straight line to the bottom of the sea. This straight line descends parallel to itself. Let every part of the suspended cable descend to the bottom by its weight in water, with the velocity v, the speed of the ship being c, then the angle a between the cable line and the horizon is determined by the equation

$$(1) \qquad \tan a = \frac{v}{c},$$

if we assume that for a portion of the cable descending in the water parallel to itself the distance is proportional to the force w, the weight of the unit of cable in water may be resolved into two components, one of which, $w \cos a$, draws the cable towards the bottom in a direction at right angles to the cable line, whilst the other, $w \sin a$, draws the cable in the direction of its axis, and down the incline formed by the water, by which it is supported. The total action of the latter two forces is $w\,l \sin a$, l being the length of the suspended cable; or, as $l \sin a = h$, the depth of the water, the total strain, $P = wh$, is equal to the weight of the portion of cable hanging from the stationary ship vertically to the bottom.

If the cable is not retained in the ship by friction, the strain P is met only by the friction opposed by the water to the sliding of the cable in the direction of its axis. The amount of this friction depends upon the condition of the surface and upon the diameter of the cable. In heavy cables sheathed with iron, this amount, compared with the specific gravity of the cable, is so small, that the much greater portion of the strain P, or wh, has to be counterbalanced by friction on board the ship, else the cable would descend too quickly, and much of it be wasted.

In order to determine the necessary amount of this frictional resistance to be established on board the ship at any moment, it is necessary to know the depth of the sea at any part where the cable is to pass, and to have a dynamometer indicating continuously the amount of strain with which the cable leaves the ship. Further, as the horizontal component of this strain checks the progress of the vessel, it is necessary to move the ship with a force sufficient to overcome this resistance and to give the required speed. Therefore, when the cable-ship had been provided with a brake of sufficient power, and with dynamometer which the author had constructed similar to a chain-balance, and when the cable-vessel (her engines being too small to overcome the strain of the heavy cable), had been taken in tow by another and stronger steamer, then the cable was successfully paid out between the previously mentioned places.*

The forces acting on the falling cable are gravity and the opposing forces of friction. Of the latter there is first the sliding friction, which acts in the direction of the cable, preventing its sliding down the inclined cable line, and secondly the friction combined with displacement of water acting in a direction perpendicular to the cable line. The latter force is proportional to the square of the velocity; the former proportional to the velocity itself. Longridge and Brooks supposed both forces to be proportional to the square of the velocity; they obtain, therefore, incorrect results, especially in determining the strength of the brake to be applied on board the ship. In stating the equation, $\tan a = \frac{v}{c}$, the author also assumed the velocity of descent at right angles to the cable-line to be proportional to the force, but it will be shown later that this is almost exactly the case in those values of the angle a that generally occur in cable-laying. The author's supposition, that the cable forms a straight line if the speed of the vessel be uniform, does not depend upon the action of the frictional forces. The cable always forms a straight line of such inclination, that of the two components of gravity, the one, acting in the direction of the cable, is counterbalanced by the sliding friction and the brake on board the ship; the other, acting at right angles to the direction of the cable, is counterbalanced by the friction combined with displacement of water. This gives equilibrium of motion, and therefore the motion is uniform.

The author then proceeds in the first part of the paper to a minute mathematical investigation of the various forces, which are at work in the laying of submarine cables, as well as the brake-power required under the varying conditions that are to be met with. Another means of settling experimentally this latter point, which was proposed by the author's brother, Dr. C. W. Siemens, is alluded to.

This is effected by keeping the speed constant and increasing the pressure of the brake until further increase of pressure is no longer followed by decrease in the velocity with which the cable is paid overboard. Then when we have found the brake-power necessary to lay without slack, with a given speed, it is easy to alter the pressure of the brake until any desired slack be obtained. But violent motion of the vessel, combined with irregularity in the velocity with which the cable runs out—an irregularity caused by the motion as well as by more considerable inequalities in the sea-bottom—will often render even this expedient ineffective.

To obtain precisely any desired slack, the only method will be to pay out, with the cable, a rope or wire having approximately the same constant velocity with which the cable descends vertically through the water, and also the same velocity of fall when the cable line is horizontal. If this wire or rope be retained with sufficient brake-power to be paid out without slack, and, therefore,

* The meditations about the laying of cables, exposed above, represent the author's views on the subject at that time.

with tension on the sea-bottom, a counter will give the exact progress of the vessel, even without the errors caused by currents; therefore the brake has only to be maintained under the pressure that will give any desired ratio between the velocities with which the cable and the wire are run out. The greater expense incurred by the use of the wire will be more than compensated for, because the wire or rope paid out without slack does not measure the progress of the vessel in a horizontal direction, but the length of the ground passed over, and it therefore defines the amount of cable necessary to follow the inequalities of the sea-bottom without strain upon the cable; and as the usual amount of 10%—15% slack is generally paid-out, to avoid the danger of any such strain on uneven ground and also the formation of catenaries of great length, it will be seen that the cost of the wire would be fully covered by economy in the amount of cable paid out.

Messrs. Longridge and Brooks* afterwards made extensive researches into the theory of cable-laying. The mathematical part of their treatise is not to be disputed, and gives an accurate description of the curve formed by a cable suspended in an oblique direction in water, if paid out with strain upon the sea-bed. But the physical part of the work, and the practical consequences drawn from it, are open to grave objections, as one of the first principles taken for granted, which materially influences the result, is incorrect. Further, the work is deficient as regards a clear perception of the principal factors and a lucid exposition of the results.

The author in the second portion of the paper treats of the localization of faults on submarine cables.

In order to insure long service, the insulation of a submarine cable or subterranean conductor must be perfect; that is to say, the resistance of the insulating coating must be equal to that defined by a calculation based upon the specific resistance of the insulating material employed. As soon as this resistance is observed to decrease, it may be assumed that in one or more places the water has come into communication with the conductor through an opening in the insulator. This may happen during manufacture of the cable, but often it is first discovered during paying-out, or some time after the cable is laid. Therefore, during the manufacture, as well as during the laying of the cable, and after it has been laid, its physical properties are submitted to continuous tests. If the existence of a fault is discovered, it is very important to determine its place or its distance from the ends of the cable. When the cable is being paid out it is necessary to arrive at this determination as shortly as possible, to enable the vessel (provided the fault be near the ship) to take in the portion of the cable recently paid out and containing the fault. The author published in 1850† his theory of determining the distance of a fault. The principle of his method is, to obtain by means of two measurements of currents or resistance, two equations, which will enable us to eliminate the unknown resistance of the fault, that is to say, the resistance which is opposed by the fault itself to the passage of the electricity to earth; it then being possible to define the ratio of distance of the fault from both ends of the conductor. The current may be measured at once from both ends of the insulated conductor, the distant end being once insulated, once in connection with the earth; or the determination may be made by two measurements from the same end, the distant end being in the first instance insulated, in the second measurement put to earth. Measurements of currents being less reliable and more difficult to obtain than measurements of resistance, the author subsequently* modified his formulæ based upon measuring currents, substituting those for measuring resistances, as soon as he had succeeded in determining a definite unit of resistance which could be easily reproduced, and had employed this unit in the arrangement of an exact scale of resistance similar to a set of weights.†

Let $a\,b = l$ be the insulating conducting wire, of which the length and resistance are known; x and y the distances of the fault from a and b; and z the resistance of the fault. Then the distance x from the end a is determined by the following equations:

(1.) $\frac{x}{y} = \frac{w}{w_1}$, when both ends are in the testing-room, and w and w_1 are the bridge-resistances, no current passing through the galvanometer.

(2.) $\frac{x}{y} = \sqrt{\frac{a\,(c-b)}{b\,(c-a)}}$, a and b being the resistances measured from both ends, with the distant end to earth, c the resistance of the whole wire, when faultless.

(3.) $x = \frac{a_1 - b_1 + c}{2}$, a_1 and b_1 being the resistance measured from both ends, with the distant end insulated.

(4.) $x = (c-b) + \sqrt{(b_1 - b)\,(c-b)}$, measuring from one end of the conductor for the determination of the distance of the fault.

In the first case the variable resistance of the fault, as well as the polarization there taking place, are entirely eliminated, because both determining measurements are taken simultaneously; this method, wherever it can be employed, thus determines the position of the fault with sufficient accuracy. But the case is very different when the ends of the conducting wire are at a great distance from each other, as in a submarine cable. The fissures through which the water comes into contact with the conducting wire are very small, often scarcely visible to the naked eye, and the resistance they offer to the passing current is extremely variable. Further, the polarization at these faulty places is often very considerable, and varies widely. Therefore measurements as indicated by the preceding formulæ seldom give satisfactory results, unless the fault be large, and its resistance consequently small.

Messrs. Clark and Jenkin have recently published two methods of determining the position of a fault in paid-out cables. These methods do away

* Longridge and Brooks *On Submerging Telegraphic Cables.* Proc. Inst. Civil Eng. vol. xvii.

† Pogg. Ann. Bd. lxxix. p. 192.

* Outline of the principles and practice involved in dealing with the Electrical Conditions of Submarine Electric Telegraphs. By Werner and C. W. Siemens. 1860.

† Pogg. Ann. Bd. xc. p. 1. Bd. xciii. p. 91. Bd. cxx. p. 512.

with much of the uncertainty to which the author's previous methods were liable from the variation in physical properties of the faulty place. Mr. Clark insulates one end of the conductor and inserts between the other end and the earth a battery and a known resistance. Then perfectly uniform electrometers are employed to measure the difference between the potentials before and behind the resistance, and at the same time the potential of the insulated end of the conductor. The latter gives the potential existing at the fault. Now let w denote the inserted resistance; P and P′ the measured potentials of its ends; p the potential at the fault measured at the other end of the conductor; and x the resistance of the conductor from the station where the battery is inserted to the fault. Then we have—

$$P - P' : w = P' - p : x;$$

$$x = \frac{w\,(P' - p)}{P - P'}$$

It being supposed that P, P′, and p are measured simultaneously, either in absolute measure, or with perfectly uniform instruments, the variability of the resistance of the fault will not influence the result. At the same time the influence of polarization at the fault is eliminated, which has only the effect of increasing the potential at the fault and therefore acts like an increase of resistance of the fault

The method published by Mr. Jenkin is based upon simultaneous measurements of the current passing through the fault and of the potentials of both ends of the conductor. To obtain this, a battery and galvanometer are inserted between one end of the conductor and the earth, the other end of the conductor being insulated. Besides this, both ends are connected with electrometers.

Mr. Jenkin's formula takes into account the decrease of current caused by the insulating coating, and, as in the case of slight faults, which are the most difficult to determine, imperfect insulation is of considerable influence, Mr. Jenkin's formula would be of great value, provided the simultaneous measurement of a current and two potentials, in absolute measure, at different places, and with sufficient accuracy to render the results reliable, did not prevent to a certain extent the practical use of it.

From what has been said, it follows that a method of determining faults cannot give reliable results unless it eliminates the very inconstant resistance and the variable polarization of the fault. Further, in faults of great resistance, occurring in long conductors, it is necessary to take into consideration or to eliminate the insulation-current, that is to say, the absorption-current, or current of electrification, passing through the whole length of the insulator as far as the cable is faultless. Again, the method must be capable of being carried out easily and quickly.

ROYAL SOCIETY.

(Continued from page 64.)

WHILE making these measurements, we noticed in a nearly dark room that when the point was negative a glow, in form like a paraboloid, was seen surrounding it long before the spark passed, and its appearance afforded, by its increasing brilliancy, useful information to guide us as to the more cautious approach of the terminals; gradually the sugar-loaf-like glow extended to the positive terminal. With 1,800 cells the glow was seen when the terminals were 0·0545 inch apart, the spark passing at 0·0344 inch; with 2,400 cells the glow began at a distance of 0·0865 inch, the spark passing at 0·0535 inch. Moreover, it was noticed that the disc (positive) became covered all over with a peach-like bloom, which became stronger in the centre as the terminals were made to approach each other, giving rise to Newton's iridescent rings.

In order to study more effectually the phenomena accompanying the glow preceding the spark, the whole series of 5,640 cells was used, the terminals being a point as before of 30°, and sometimes a flat disc of 1·1 inch in diameter, or a slightly convex one of 0·8 inch in diameter for the other. In all cases a peach-like bloom deposited on the disc, which was connected with the silver (positive) terminal; and when the flat disc was used the deposit was notably greater at the periphery and the centre than in other portions of it. With this number of cells, with the flat disc the glow occurred at 1·073 inches, the spark at 0·139 inches; with the slightly convex disc the glow occurred at 1·124 inches, the spark at 0·140 inches.*

To ascertain whether a current really passed when the glow appeared, various vacuum-tubes were interposed in circuit between the battery and one of the terminals. In all cases they were illuminated even before a glow was perceptible on the negative pole. Their interposition, as was to be expected, shortened the spark and diminished the distance at which the glow was perceptible. For example, with a hydrogen tube, having a capillary portion between two larger tubes, such as is used for spectrum experiments, and offering a resistance of 190,000 ohms, the glow occurred at 0·939 inch, the spark at 0·092 inch.

A tube of 31 inches between the terminals, and offering a resistance of 350,000 ohms, was brilliantly illuminated when interposed between one terminal and the battery. When the terminals were separated the extreme range of the discharge was 1·2 inch, and before any glow was visible at the negative electrode. How much further between the electrodes it will be possible to obtain a current has yet to be determined with a larger discharger now in course of construction.†

I have alluded to the resistance offered by vacuum-tubes. At first I experienced considerable difficulty in measuring it. For example, when in a Wheatstone's bridge the resistance of the tube was balanced by inserted resistances, the galvanometer could only for a short time be brought to rest, and it was then found that the cause of this was that the the tubes rapidly increased in resistance as the current passed. After a time, however, they recovered their original resistance, sometimes rapidly, sometimes only after the lapse of days. The resistances were found not to be dependent on the length of tube, but to a great extent on their bore, capillary tubes offering a considerable resist-

* Postcript, January 7.—At the suggestion of Professor Stokes, who saw the experiment repeated, the point was made positive, when a longer spark was obtained, namely, 0·154 inch and 0·164 inch.

† Postscript, January 8th.—A current was obtained with the negative point distant 4·1 inches from a positive plate 6 inches in diameter.

ance. Ultimately it was found that it was better to discard the indications of the galvanometer, and to rely solely on the appearance of a luminosity in the tubes placed on one side of Wheatstone's bridge as soon as the insertion of a balancing resistance was made in the other.

Later on we hope to have the honour of sending to the Society a more detailed statement of our experiments in support of those now quoted, and in confirmation of our former paper on the cause of stratification in electric discharges *in vacuo*.

In conclusion, we venture to draw attention to the following consequences of the law of the length of spark being dependent on the ratio of the square of the number of cells of a voltaic battery, in the event of its being confirmed by experiment. Taking as a basis the spark with 600 cells of the rod-chloride of silver battery = 0·0033 inch, a unit of 1,000 such cells would give a spark of

$$\frac{0033 \times 1{,}000^2}{600^2} = 0{\cdot}009166 \text{ inch},$$

one hundred units (100'000) a spark of 91·66 inches,
a thousand units (1,000,000) „ 91·66 „
= 764 feet nearly, whereas a single cell would have a striking distance of $\frac{1}{1090000}$ of an inch only. As far as our own experiments have gone the law has been confirmed; and although a million cells will probably never be made, a hundred thousand come within the range of experimental possibility.

DESCRIPTION OF A LIGHTNING PROTECTOR ESPECIALLY ADAPTED FOR AERIAL LINES.

By J. E. VAES.

A ring of metal (fig. 1) about 1½ centimetres wide, and 2½ centimetres in diameter, is cut in two. On one side the two halves are held together by means of a hinge, and on the other side they shut by means of a screw. This ring encircles a bobbin of hard wood, also cut in halves, and bored through its axis. The raised edges of this bobbin prevent the metal ring slipping off. In the interior of the ring is fixed a protecting point of alluminium, bronze, or platinum, which extends within a distance of one or two millimetres of the groove in the bobbin (figs. 2 and 3).

To apply the protector to a telegraph wire, the ring, and with it the two halves of the bobbin, (fig 3) are opened and placed on a wire of the same gauge as the groove in the wood. The ring and the bobbin are then closed with the screw, care being taken to pass under the head of the screw a copper wire covered with guttapercha, the other extremity of which is connected with a plate of metal attached to the bottom of the post, and making a good earth connection.

The lightning protector following all the vibrations of the wire, it is impossible that there can be a contact between the wire and the protecting point, and the point itself is excluded from atmospheric influences.

Remarks.

1. The diameter of the groove in the bobbin should be slightly smaller than that of the wire to which it is intended to be fixed.

2. To fill up the chinks that will always exist to a greater or less extent between the two halves of the bobbin, it is sufficient to introduce, before fixing to the wire, a thin layer of guttapercha or tarred cloth: these substances giving way to the pressure, fill up the chink entirely.

3. In case of rain, the lightning protector might give rise to derived circuits, owing to the short distance between the exterior of the metallic ring *a*, and the wire *b* (fig. 2). Several methods suggest themselves to remedy this defect. It would be insufficient to apply a coat of varnish to the metallic parts, it would therefore be better to lengthen the bobbin so as to increase its length on either side of the ring, or even to heighten the edges of the bobbin.

Another method consists in covering the wire with an insulating material for a distance of some centimetres on each side of the protector. That which appears the simplest, and at the same time the most effective plan, is to surround the lightning protector with a covering, thus removing it from the influences of rain. Owing to its small dimensions (the protector can easily be covered with the hand), the application of this last suggestion would not be difficult.

Fig. 1.

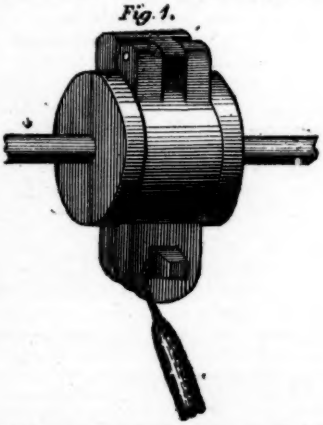


Fig. 2.

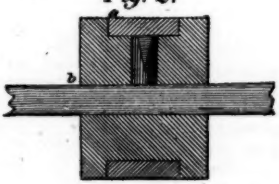
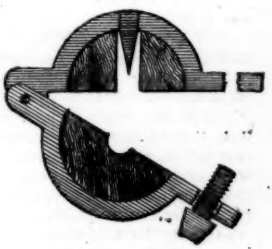


Fig. 3.



4. It is unnecessary to say that whilst retaining all the principles on which the construction of the protector is based, it can be varied in different ways, as for instance, by replacing the protecting point by several points, or by a small plate of metal provided with teeth, &c.

5. This protector can be applied without making any special alterations to the posts. One is not limited in choice of position, and the lightning can thus be given the possibility of expending itself at a convenient distance from instruments and cables, which will find themselves in case of storms much less exposed to derived circuits.

In the month of August in the past year, I had a lightning protector constructed on this principle, but have not yet had occasion to test its practical value.

FARADAY AND WHEATSTONE.

We have recently published Faraday's lecture, delivered in 1858, on Wheatstone's A B C Telegraphy, and more recently still the Bakerian Lecture of 1843, delivered by Wheatstone. Our readers will be interested in reading the three following letters which refer to these subjects which have been found amongst Sir Charles Wheatstone's papers :—

(Copy.)

Royal Institution, 4th May, 1840.

Dear Wheatstone,—Thrice have I endeavoured to catch you at home, but failed. My object is to ascertain whether you can let me have the Telegraph subject this season as you said at the beginning of the year, and if so, whether the last evening, the 12th of June, would suit. As I have not seen much of it lately, *I should want cramming*, but will prepare as soon as I know your mind. You know my desire to present your beautiful developments to our audience, and I know I may count on your willingness, but cannot tell as to your convenience. Let me know quickly, for I must now arrange the rest of the evenings.

Ever yours,

(Signed) M. Faraday.

C. Wheatstone, Esq.

(Copy.)

Royal Institution, 27th November, 1843.

Thanks, my dear Wheatstone, for your most *valuable paper*; it is a great pity that it did not appear in the Phil. Trans. long ago. The only alloy to my pleasure in the reading of it was the continual baulking by the errors of reference made, I suppose, either by the engraver or printer. Thus, at p. 323, the references to fig. 5, I cannot follow throughout on the plate. At. p. 326, fig. 9 means, I conclude, fig. 8 of plate, but if so, then the letter E is wrong in one or the other. If these are not mistakes of mine only, then it would be well if they could be corrected in the plates before the transactions are sent out, supposing that possible.

Let me hope that you will carry out your paragraph 8 with respect to all bodies; it identifies itself with my paragraph, 1871, etc. Then, where is excitement by contact?

Ever truly yours,

(Signed) M. Faraday.

C. Wheatstone, Esq.

(Copy.)

Royal Institute, 19th January, 1858.

My Dear Wheatstone,—Whilst thinking on your beautiful telegraphs, it occurred to me that perhaps you would not think ill of my proposing to give an account of the magneto-electric telegraph and of the recording telegraph at a Friday evening after Easter. About the end of May or June, I suppose all would be safe by that time. I think that by the electric lamp and a proper lens we might throw the image of the faces on to the wall, and so well illustrate the action to the whole audience. Let me know generally whether you may be inclined.

Ever truly yours,

(Signed) M. Faraday.

Correspondence.

A New Method of Signalling on Railways, by Sir David Salomons, Bart.

Broomhill, Tunbridge Wells,

February 17th, 1876.

Dear Sir,—I perceive you have kindly taken notice of my pamphlet in your journal. It appears that you have only seen the first edition, which was written to explain the large model (which acted perfectly,) which was exhibited at Willis's Rooms, Cannon Street Hotel, the Crystal Palace, &c. I own that the method detailed in full, was simply "illustrative," and not "practical." In the appendix a method for *use* is shortly described, and in the edition I now send you, you will find it clearly drawn out under the name of the "Wire Method." The central rail system might however be employed to covered railroads. Some of the instruments connected with this system are well adapted for telegraphic purposes, and I use them for such purposes here. With many apologies for troubling you in this matter,

I remain,

Yours faithfully,

David Salomons.

We publish with pleasure Sir David Salomon's letter, and in reply to it have merely to say that our remarks were the result of a careful perusal of the latest edition of his pamphlet. In selecting his "central rail system" for description, we were induced to do so simply because it appeared to us as the most reliable of the two, and as fairly embodying the principle conveyed by the "wire system." With the latter, as with the "central rail system," the absence of a signal indicates safety, and our objection to it, on this score alone, remains the same.—Ed.

To Correspondent.

*** Duly authenticated contributions, theoretical and practical, on every subject identified with the interests to which "The Telegraphic Journal" is the organ, will always command attention. Anonymous correspondence will be wholly disregarded. Literary communications and books for review should be addressed to the Editor; business communications to the Publishers, 10, Paternoster Row, E.C.